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How Cities Shrink: Complex Pathways to Population Decline

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Abstract

Factors contributing to urban shrinkage have been widely discussed in the urban studies and planning literature, however the emergence, influence and interaction of these factors in urban shrinkage processes have received little attention. This paper builds on the established circular causality of urban shrinkage processes by empirically examining the time series relationship of fifteen demographic, migratory, labor and built environment factors. The causes of urban shrinkage are inherently context dependent. However many decisive contributing factors, such as low birth rates and economic restructuring, are often considered to be outside of the influence of the local context. Empirical knowledge of how these factors manifest and interact with other factors at the local level is limited. Crosscorrelation network analysis is developed to disentangle the complex processes and explore the regional differentiation of urban shrinkage. Two Canadian shrinking cities, Chatham-Kent, Ontario and Cape Breton Regional Municipality, Nova Scotia are examined over a period of seventeen years from 1997 to 2013. Results indicate that factors in the urban shrinkage process are strongly interrelated and exhibit circular trends and feedback mechanisms. The analysis shows significant regional differentiation as each case study had a distinctive set of processes that preceded the changes in migration and natural population balances that led to population loss. However, among the urban shrinkage processes in both locations, unemployment, employment and labor participation rates were found to be indicative of immigration and emigration trends. Additionally, changes in unemployment had a negative relationship with housing permits and intraprovincial migration was strongly linked to changes in housing starts and completions.

Introduction

The dominant narrative of urban shrinkage research asserts that population loss and economic restructuring stem from the interplay of macro economic and demographic trends at the local scale (Rink et al., 2012). However, few studies have attempted to disentangle and study the interdependent relationships amongst variables related to shrinkage using quantitative methods. Economic and demographic trends undoubtedly play a central role in the development of urban shrinkage, but are also part of a larger complex system complete with interdependencies and feedback loops. The relationships between economic, demographic and other processes must be taken into consideration in order to gain a more robust understanding of the evolution of urban shrinkage. Within a nonlinear system, how do economic and demographic processes related to urban shrinkage evolve at the local scale? And furthermore, how can the complex relationships between contributing factors be captured, represented and analyzed?

Empirical research examining the dynamic processes of shrinkage is necessary in order to grasp the nonlinear interdependencies between the causes and effects (Großmann et al., 2013). Hoekveld's (2012) work on the temporal and spatial aspects of shrinkage in the Netherlands is one of few studies to examine the complexities of shrinking trajectories. She concludes that the individual processes leading to shrinkage are strongly interrelated and display feedback mechanisms and circular causal trends.

This paper contributes to the effort to disentangle the causes and effects in the shrinking process. It does so by examining the relationships between fifteen demographic, migratory, economic and built environment factors in two case studies over a period of seventeen years from 1997 to 2013. It follows and builds upon Hoekveld's (2012) cross-correlation methodology by expanding the variables and integrating network analysis and visualization. The cross-correlation network analysis approach is applied to the Canadian case studies of Chatham-Kent, Ontario and Cape Breton Regional Municipality (CBRM),

Nova Scotia to determine the order and influence of contributing processes to urban shrinkage. The analysis unpacks the processes leading to and stemming from urban shrinkage, providing insight into the complexity of shrinking city systems.

Circular Causality of Urban Shrinkage

Broadly speaking, a shrinking Canadian city is a municipal district with a minimum population of 10,000 residents that has faced population losses for more than two years and is undergoing economic transformations with some symptoms of a structural crisis (adapted from Pallagst et al., 2009; Wiechmann, 2008). Although cities have been transforming, losing and gaining population since their inception, the recent phenomenon of urban shrinkage is considered distinct from historical population loss. Martinez-Fernandez et al. (2012) contend that modern urban shrinkage is a socio-spatial manifestation of globalization. The emergence of a global economy and the internationalization of the production process have altered manufacturing, distribution and consumption systems (ibid.). This has contributed to the shrinkage of industrial cities across the globe. The mobility and uneven development of human, financial and knowledge capital has assured the significance of large global cities (Sassen, 2001; Weaver & Holtkamp, 2015). And the global shift of populations to urban centers has been reinforced by new immigrants' tendencies to settle in larger, metropolitan regions (Skeldon, 2014).

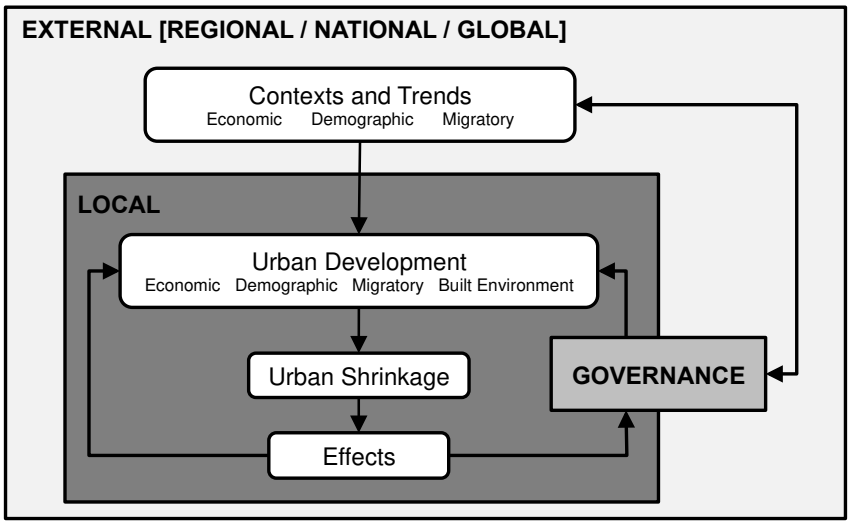

Figure 1: Conceptual model of urban shrinkage (adapted from Haase et al. 2013)

Castells' (2004) network society presents cities as nodes in an information network. He postulates that the global economy has prompted capital and labor to concentrate in specific nodes of great importance while weakening nodes of lesser connectivity. This uneven flow of capital and information has allowed economic and demographic trends to self-perpetuate in both global and shrinking cities. This cyclical trend is outlined in Figure 1, which depicts a conceptual model of urban shrinkage. Changing economic and demographic contexts and trends, at varying scales, have consequences for local urban development. This can lead to population decline, which in turn impacts urban development (Haase et al., 2013). This cyclical mechanism can be further reinforced by changes to migratory trends and the degradation of the built environment. The governance context also plays a crucial role in guiding and shaping urban development. The feedback loops, present at the local and external scale, can influence and be influenced by governance. This can potentially lead to further reinforcement of demographic and economic feedback mechanisms (ibid.). These dynamic processes continue to have direct and indirect impacts on local urban development.

Due to the circular causality of the processes in shrinking cities, effects of the process can in turn become drivers (Haase et al., 2014). The continued population and economic decline in shrinking cities is

often a result of self-reinforcing feedback mechanisms. Many researchers have recognized the multidimensionality of urban shrinkage (Martinez-Fernandez et al., 2015; Pallagst et al., 2009). However little work has been done to disentangle the temporal dimension of these processes. Influenced by Jay Forrester (1971), the research presented in this paper integrates elements of system dynamics to shed light on the multidimensionality of urban shrinkage processes. Specifically this study explores the interrelationships between economic, demographic, migratory and built environment processes in two shrinking case study cities. The theorized direct relationships between the overarching variables are depicted in Figure 2 (see Methods section for full description of variables).

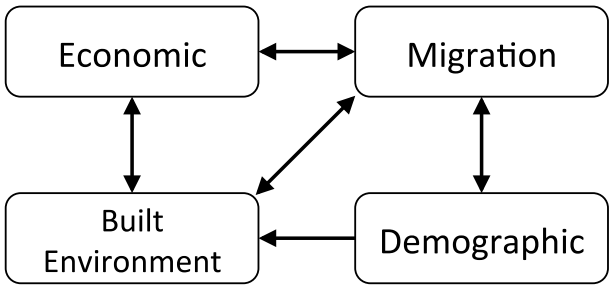

Figure 2: Theorized relationships between economic, migration, demographic and built environment processes in shrinking cities

It is hypothesized that there will be a two-way relationship between economic and migratory variables. Local economic prospects play an important role in the decision to move into, or out of, an urban area. The relationship between economic and built environment variables is also expected to be reciprocal. An increase in unemployment could have a negative effect on housing starts and completions. Such an effect could in turn reduce employment in construction-related industries. Migration and the built environment are also expected to influence one another as housing prospects may influence migratory decisions and changes in migratory patterns would impact the housing industry. Demographic change could also impact the built environment as housing purchasing trends and preference change with age. An

aging population may be less likely to purchase newly developed homes. Lastly, a two-way relationship is expected between demographic and migratory variables. It is unlikely that in- and out-migrants will be equally distributed across the population, and therefore a change in migration will impact birth and death rates, as well as dependency ratios. Of course the specific relationships between variables are extremely context dependent. Historic local, regional, national and global processes all shape local urban development.

Methods

Time series analysis is often applied to investigate temporal relationships. However, capturing the intricacies of feedback loops and cycling mechanisms within and between the processes can be very challenging. This paper follows and builds upon Hoekveld's (2012) approach to representing and analyzing complex time series data. Cross-correlation network analysis is able to capture the strength, time and direction of processes in complex systems. This approach allows for deeper analysis and comparison of complex system trajectories. This section explains and defines the cross-correlation function, the variables in the study and the network visualization approach.

Cross-Correlation

In many complex systems, like shrinking cities, a change in one variable precedes a change in another. In order to measure the time and direction, as well as the strength of the relationships between variables, cross-correlations coefficients are calculated. Essentially, cross-correlation coefficients are used to determine how one set of variables is related to past lags of another set of variables (Gottman, 1981). This time series analysis technique is often used in signal processing research to determine the time delay between signals (Knapp & Carter, 1976). Figure 3 shows an example of two highly correlated time series,

y_t and x_t. Because of their lack of synchronicity, a simple correlation calculation would not capture the full extent of their relationship. Using the cross-correlation function in SPSS, we are able to examine the relationship between these time series' while taking into account a potential lag between them. For example, if we considered x_t to be employment and y_t to be population, results would show that the two are highly correlated with a change in employment preceding a change in population by a lag of t_2-t_1.

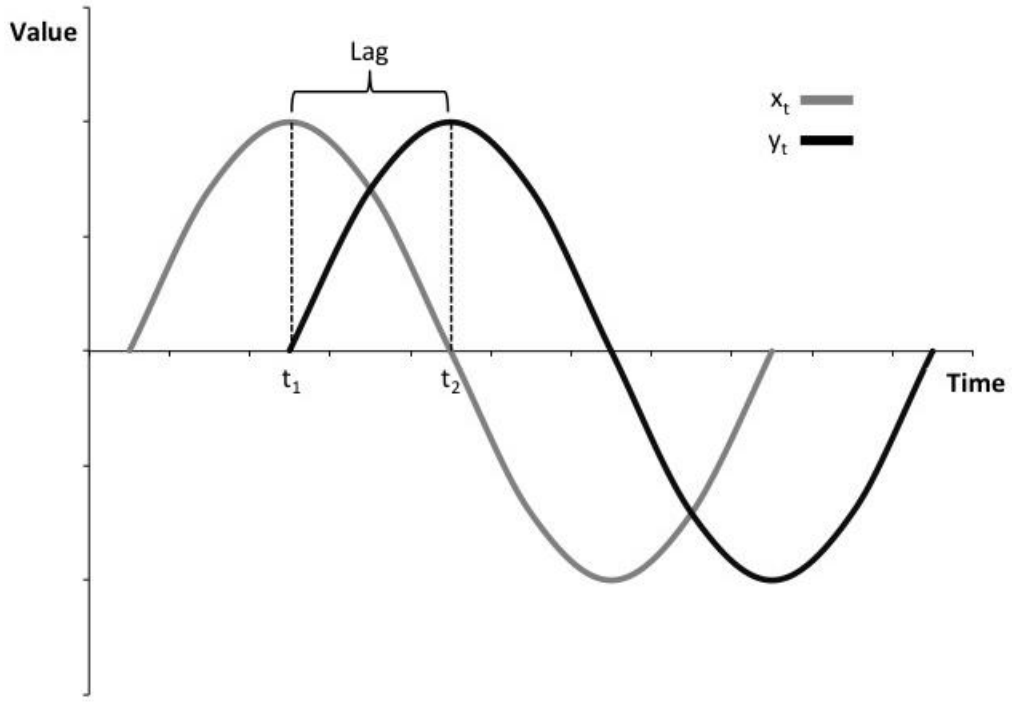

Figure 3: Example of two highly correlated, but lagged time series (author's illustration)

From the calculated coefficients it is possible to conclude the significance and direction (which variable precedes which) of the relationship at different lags. For this study, the lag range was from zero to five years. In other words, cross-correlation coefficients were calculated for each lag from zero to five years for every pairwise relationship. Essentially, this determines if a change in one variable preceded a change in another by zero, one, two, three, four or five years. Only relationships significant at the 0.01 level were included in the analysis.

It is important to note that cross-correlation analysis does have limitations. The temporal relationship between changes in variables may demonstrate coherence but cannot establish causality. Cross-correlation findings alone can lead to ambiguous inferences when studying several time series' simultaneously (Sameshima, 2001). Furthermore, there is a risk of false negative results as seemingly open nonlinear systems can in fact be closed due to extensive feedback loops (Billings, 2013). In order to interpret the findings in this study, rich qualitative data was relied upon to supplement empirical results from the cross-correlation analysis.

Variables

This study included fifteen economic, demographic, migratory and built environment variables collected annually over a span of seventeen years from 1997 to 2013 (Table 1). Data was collected at the local level as defined by the municipal government boundaries of the two case studies. All data was transformed to rates relative to the population, rather than absolute values. This enables a more robust comparison of values across time periods and more accurate calculation of lagged cross-correlation coefficients.

The academic literature consistently cites economic and demographic change as key drivers of urban shrinkage (Bernt et al., 2012; Buhnik, 2010; Wiechmann, 2008). This research unpacks these drivers and examines the dynamic and interrelated processes contributing to population loss. Four demographic (dependency ratio, proportion of residents aged 65 and older, birth rate and death rate) and five migratory variables (immigration, emigration, interprovincial, intraprovincial and non-permanent resident rate) are used to capture changes in the population structure and to understand local migration processes. Three labor variables (unemployment, employment and labor participation) act as proxies for local economic change. Furthermore, as the built environment has been a primary focus of shrinking cities scholarship

(Martinez-Fernandez et al., 2015), three housing-related variables (housing permits, starts and completions) are included to explore the relationships between economic, demographic and migratory changes and the built environment. The variables included in the study were strategically chosen to represent the key drivers of urban shrinkage. However, it is important to note that there are a number of alternative variables that would also be informative. Although the selection process was conceptually driven, it was also subject to data availability limitations.

Table 1: List of included demographic, economic, migratory and built environment variables

Variable Type	Variable	Source
Demographic	Dependency ratio	Statistics Canada
Demographic	Proportion of residents aged 65 and older	Statistics Canada
Demographic	Birth rate	Statistics Canada
Demographic	Death rate	Statistics Canada
Economic	Unemployment rate	Statistics Canada
Economic	Employment rate	Statistics Canada
Economic	Labor participation rate	Statistics Canada
Migration	Immigration rate	Statistics Canada
Migration	Emigration rate	Statistics Canada
Migration	Interprovincial migration rate	Statistics Canada
Migration	Intraprovincial migration rate	Statistics Canada
Migration	Non-permanent resident migration rate	Statistics Canada
Built Environment	Housing permit rate	Cape Breton Regional Municipality, Municipality of Chatham-Kent
Built Environment	Housing start rate	Canadian Mortgage and Housing Corporation
Built Environment	Housing completion rate	Canadian Mortgage and Housing Corporation

Dependency ratio is defined as the ratio of dependents (number of people aged 0 to 15 and over 65 years old) to working age population (number of people between the ages of 15 and 65 years old). Labor participation rate is expressed as the total labor force (persons above the age of 15 who are employed or unemployed and actively seeking work) relative to the size of the working-age population. Considering the volatility and unpredictability of local level migration trends (Wilson & Rowe, 2011), subcomponents of migration (immigration, emigration, interprovincial migration, intraprovincial migration and non-

permanent resident migration) are examined to gain a deeper understanding of the migration process. Net interprovincial migration captures the movement of people between provinces, while net intraprovincial migration captures the movement of people within the province.

Network Visualization

The amount of detail associated with such a range of variables provides an opportunity to further understand the relationships and feedback mechanisms leading to changes in population. However, by including this many variables and digging for a deeper analysis of a complex system, the analysis becomes just that – complex. A network approach is used to systematically analyze and visualize the fifteen pairwise relationships included in this study. The dynamic relationships of key variables are then examined in closer detail.

Visualization of the full network is used to obtain a consistent, comparable and informative visual representation of all of the pairwise relationships in the complex system (Figures 9 and 10). Each variable is represented by a node and placed evenly in a circle. The colors of the nodes indicate the type of variable (demographic, migration, labor, housing). An edge between two nodes was drawn for every statistically significant relationship (calculated using the cross-correlation function). The number in brackets next to the variable name denotes how many edges stem from that particular variable. The color of the edge depicts whether the relationship is positive (black) or negative (red). The temporal aspect of the relationship is represented by the direction of an edge's arrow (indicating which variable preceded the other). Due to the number of edges, the time lag associated with each relationship is not visually represented. Therefore a second visualization approach examining specific nodes in closer detail was necessary.

The second visualization approach focuses on the unemployment, immigration, interprovincial, and intraprovincial migration variables (Figures 11-14). These visualizations depict the dynamic temporal relationships between variables. Each visual representation is focused on one of the four aforementioned key variables. The variables that precede a change in the key variable are indicated on the left hand side with arrows pointing in. The variables that follow a change in the key variable are indicated on the right hand side with arrows pointing away from the center. The length of arrow is proportionate to the length of the time lag (also indicated above the arrow) between the processes. Once again, negative relationships are depicted in red and positive ones in black.

Case Studies

Two Canadian municipalities are the geographic focus of the study: Cape Breton Regional Municipality (CBRM), Nova Scotia and Chatham-Kent, Ontario (Figure 4). Both municipalities have populations of roughly 100,000 and a land area of approximately 2,500 square kilometers. Furthermore, CBRM and Chatham-Kent are both single-tier regional governments with one central urban community (Sydney and Chatham, respectfully) and a number of smaller urban and rural centers. Both cities have traditionally relied upon industrial-based economies and have witnessed declines in employment and population. While CBRM's economy and population have been steadily declining for decades, it is a relatively recent phenomenon in Chatham-Kent. These cities represent two Canadian shrinking city trends: long-term shrinkage in a peripheral resource-based economy and emergent-shrinkage in a central manufacturing-based economy.

Figure 4: Map of case study locations

Cape Breton Regional Municipality

Traditionally CBRM's economy has been based on coal and steel. For the first part of the 20th century CBRM grew rapidly, from a population of nearly 50,000 in 1901 to a peak population of almost 132,000 in 1961 (Statistics Canada, 2014). However, coal production peaked in 1913. Although mining employment continued to grow until the 1950s, by 1965 it had dropped from approximately 10,000 to 4,500 as more than 40 mines closed (Mason, 1991). The shift to other types of fuel, more lucrative government subsidies and the increasing difficulty accessing coal all contributed to the industry's decline. In 1967, the federal government took over mining operations mandating to phase out mines as replacement jobs could be created in other sectors. And in 1968, the provincial government established the Sydney Steel Corporation (SYSCO) to operate local steel production for 12 months until a private buyer could be found. The provincial government's one-year commitment turned into 33 years as the economy continued

to decline. Job loss in the steel and mining industries continued throughout the following decades despite billions of dollars of government investment (ibid.). In 1999, the government terminated funding for SYSCO and steel production ended. And in 2001, the closure of the Prince Mine signified the end of an industry that had been the identity of the city for almost 200 years (Wray & Stephenson, 2012).

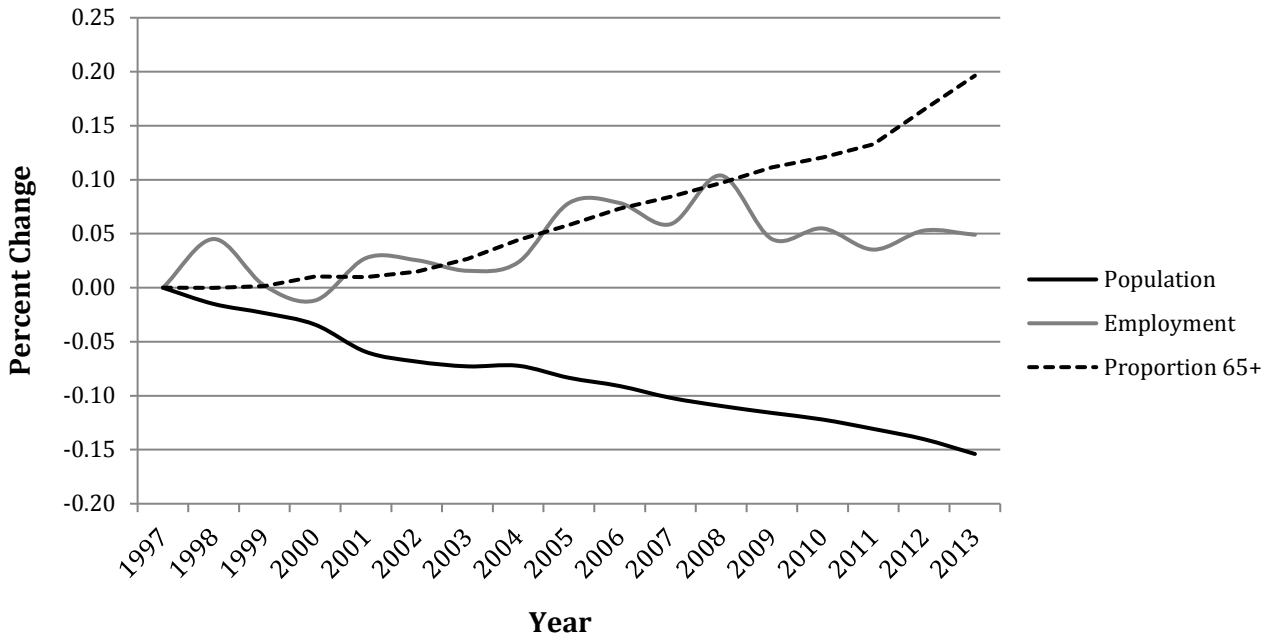

Figure 5: CBRM percent change in population, employment and proportion of population over 65 years old from 1997 to 2013 (Source: Statistics Canada)

Population in CBRM has been steadily declining for decades. Between 1991 and 2006, the city lost almost 40% of the population aged between 20 and 34 (Statistics Canada, 2012). And between 1997 and 2013 CBRM lost 15% of its population and over 20% of those who remain are over 65 years of age (Statistics Canada, 2014). Population loss is often attributed to parallel losses in employment, but as Figure 5 demonstrates, the relationship is not straightforward. From 1997 to 2013, the population of CBRM continued to decline, however during that time absolute employment fluctuated considerably despite a continued increase in the proportion of the population over the age of 65 years old.

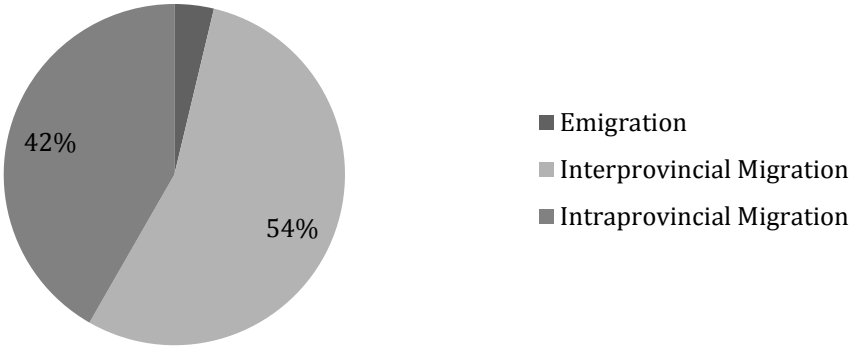

Figure 6: Proportion of population loss by migration type in CBRM between 1997 and 2013

In CBRM, outmigration is almost entirely inter- and intraprovincial (Figure 6). It is likely that, within the province, CBRM residents are moving to Halifax – the province's only large growing population center. Interprovincial migration is likely reflecting the large cohorts of Cape Bretoners who have moved to Alberta to work in the oil and gas industry (Wray, 2012).

Chatham-Kent

Chatham-Kent's economy has traditionally been based around the automotive and agricultural industries. Heavy truck manufacturing began in 1923 and continued until 2011. It was then that Navistar International – the main local employer in this industry - officially closed the truck plant despite a $65 million government investment in 2003 (Shreve, 2011). Like cities such as Detroit, Chatham-Kent is reliant on mature industries and lacks economic diversity (Jacobs, 2015). However, significant population decline only began in the mid-2000s.

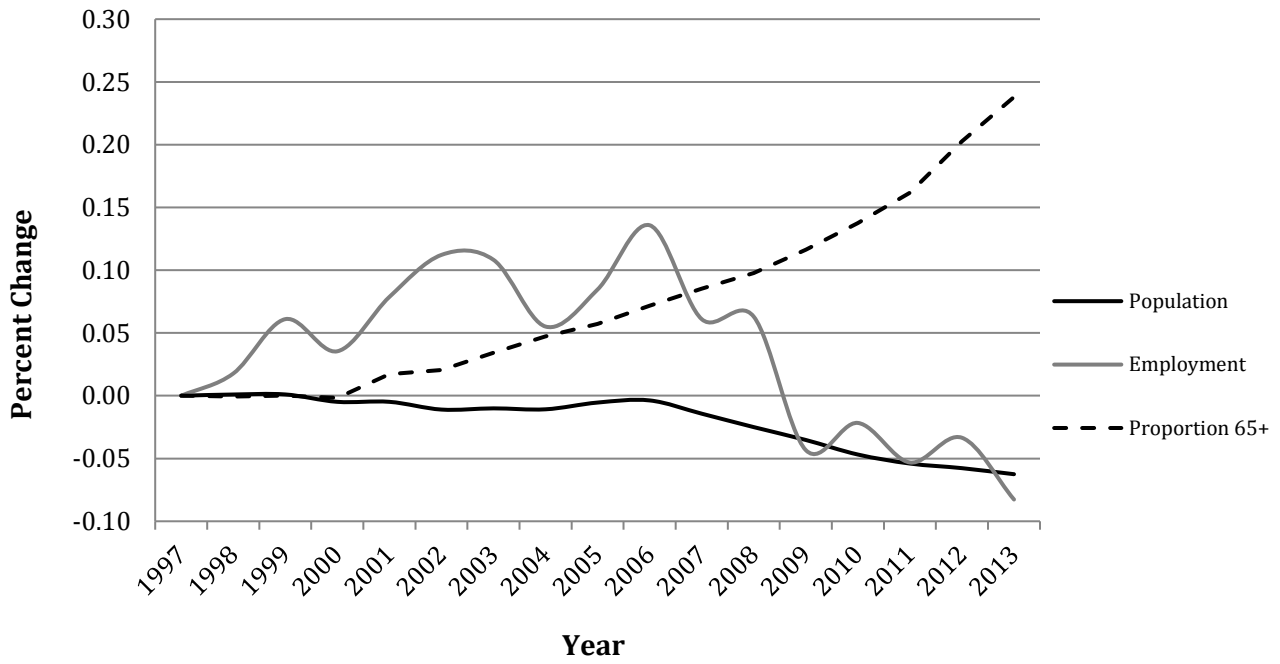

Figure 7: Chatham-Kent percent change in population, employment and proportion of population over 65 years old from 1997 to 2013 (Source: Statistics Canada)

Figure 7 shows that population change in Chatham-Kent remained relatively stagnant until 2006. Since 2006, the city has lost 6% of its population. Between 2006 and 2009 alone over 15% of the city's jobs were lost. The unemployment rate peaked in 2009 at 11.5%, but had subsided to 8.4% by 2013 (Statistics Canada, 2013). The trend in population decline is projected to continue into the foreseeable future (Ontario Ministry of Finance, 2012). Similar to CBRM, it is mostly the younger working-age population who are migrating from Chatham-Kent. As of 2013 almost 20% of the population was over 65 years of age (Statistics Canada, 2014). However, unlike CBRM, trends in population loss are very similar to trends in employment.

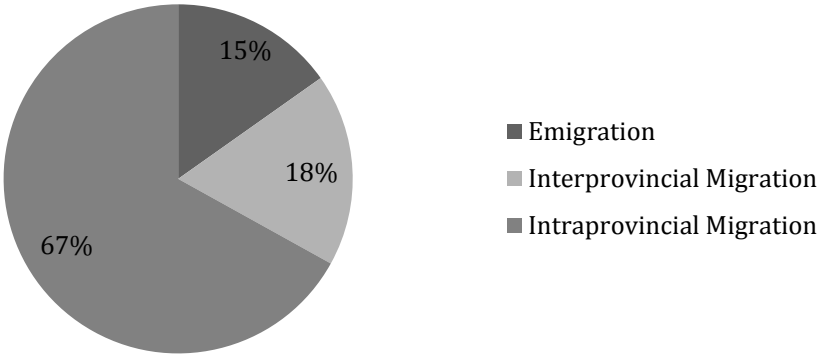

Figure 8: Proportion of population loss by migration type in Chatham-Kent between 1997 and 2013

Intraprovincial migration plays a very large role in Chatham-Kent (Figure 8). This is likely due to Chatham-Kent's proximity to the Greater Toronto Area (GTA) – one of the largest and fastest growing metropolitan regions in North America. Chatham-Kent has a much higher rate of immigration than CBRM. However, in recent years the number of immigrants has been subsiding. Within the timeframe of this study, the number of annual immigrants has fallen by 50%. Its proximity to the GTA, where approximately 40% of new immigrants settle (Murdie, 2008), increases its destination profile. However the recent decline of accessible, high-paying manufacturing jobs has likely impacted its ability to attract immigrants (Center for Regional Economic Competitiveness, 2011). The following section broadens the scope of analysis to also include economic, demographic and built environment trends in both cities to provide insight into their shrinkage trajectories.

Results

Figure 9 and 10 show the cross-correlation network maps of Chatham-Kent and CBRM respectively. The edges in the map depict the statistically significant relationships between the fifteen demographic, economic, migratory and built environment variables. For the sake of visual simplicity, time

lags are not displayed. However, they are discussed in the analysis. Full correlation tables including the associated lags for each case study are provided in the Appendix.

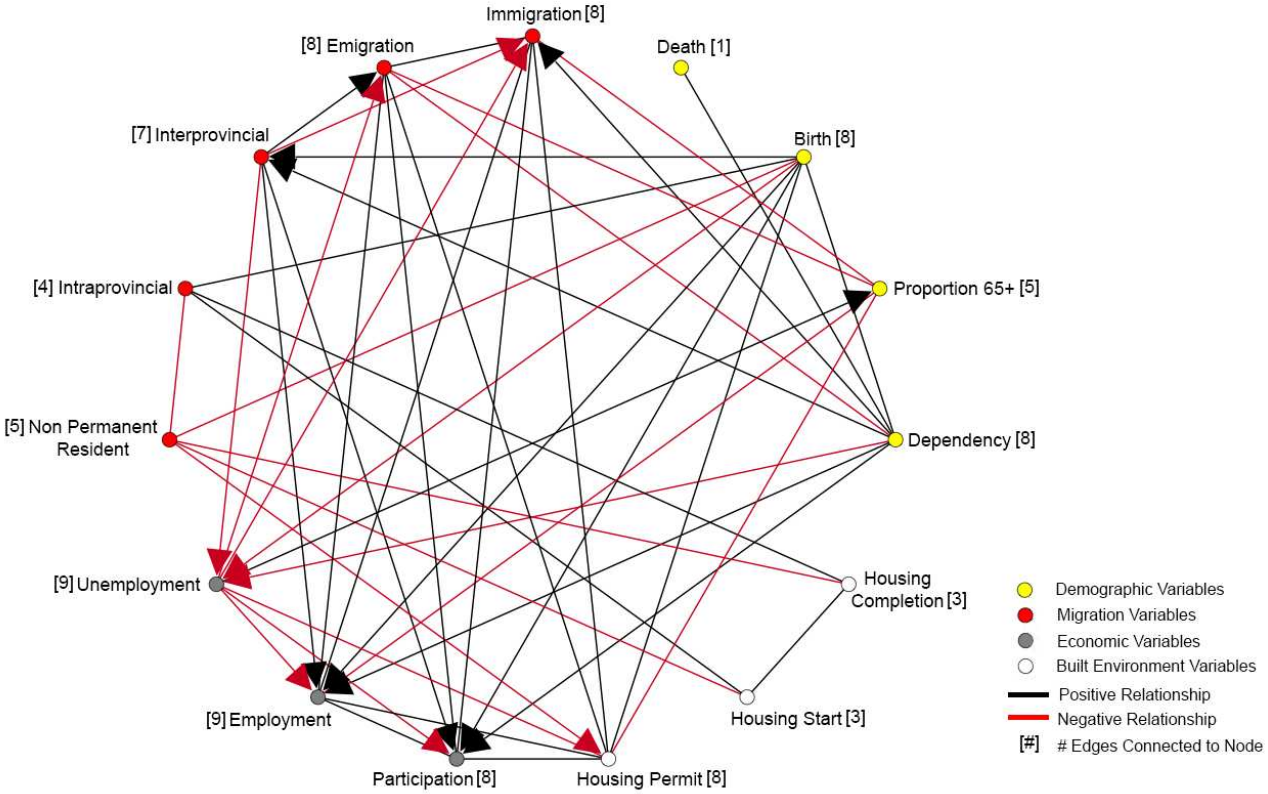

Figure 9: Chatham-Kent cross-correlation network map

There are 47 edges in the Chatham-Kent network map (Figure 9). Each represents a statistically significant cross-correlation relationship. Unemployment and employment are the most connected nodes, each with 9 unique statistically significant relationships. The least connected node is death rate, which has only one relationship with dependency ratio. 60% of the relationships are positive. The CBRM network map (Figure 10) displays more circularity and feedback loops than Chatham-Kent. In CBRM, there are 62 edges and therefore increased density and interrelation of variables in the network. Immigration is the most connected node with 12 edges, followed by unemployment, labor participation, emigration and

housing completions each with 11 edges. The least connected node is interprovincial migration rate with only one relationship with dependency ratio. Similar to Chatham-Kent, roughly 60% of the relationships are positive.

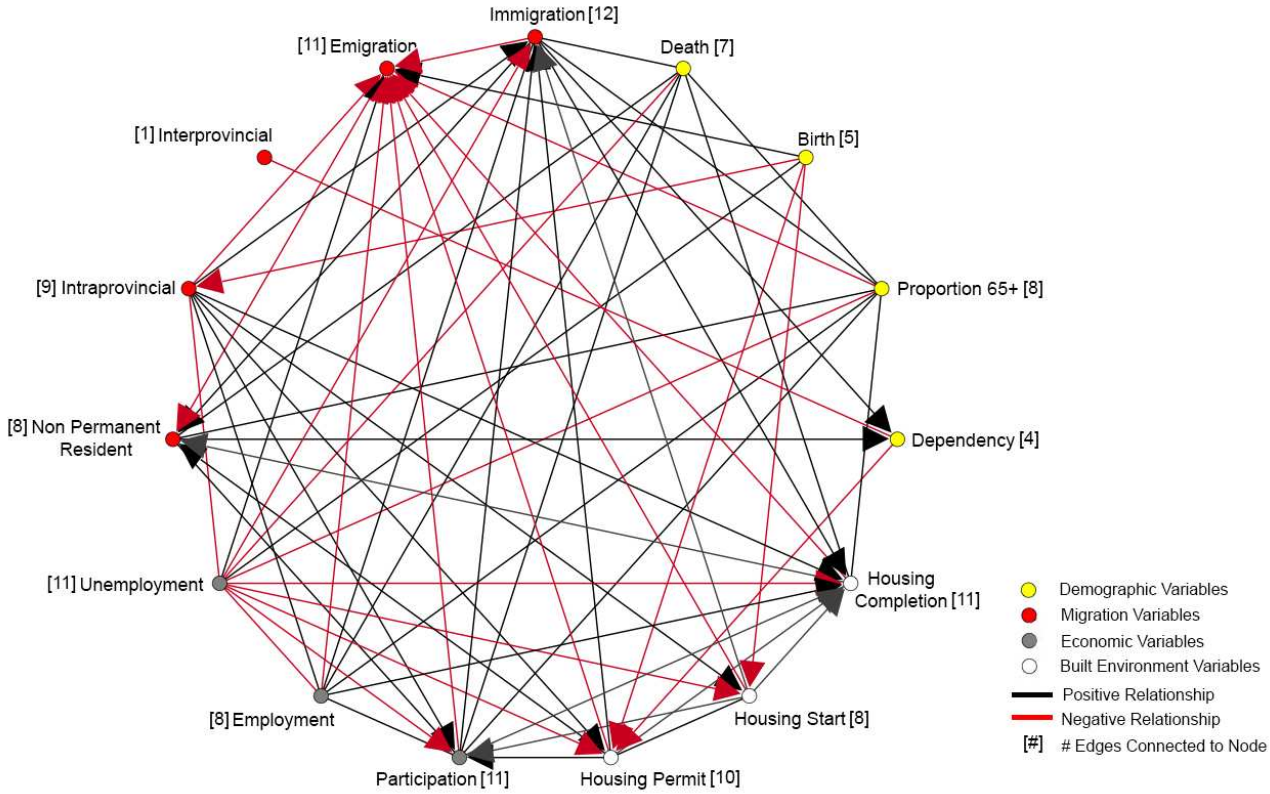

Figure 10: CBRM cross-correlation network map

Migration and unemployment are often cited in both the academic and gray literature as key factors of population decline. The migratory analysis above confirmed that immigration and intra- and interprovincial migration are the strongest migratory contributors to population change in the two case study cities. The cross-correlation network maps show that they are also highly connected to other demographic, labor and built environment variables. Looking closer at these components and their relationships within the cross-correlation network allows us to unpack the complexity and gain a better

understanding of the processes driving migration and unemployment. Due to the large number of significant relationships in the two cross-correlation networks (109 total), exploring every relationship is not within the scope of this paper. The following subsections will highlight examples of dynamic relationships and trends in unemployment and migration.

Dynamic Trends in Unemployment

Figure 11A shows that in Chatham-Kent a decrease in the interprovincial migration rate is followed two years later by an increase in unemployment. Additionally, as birth rates decrease, unemployment increases. This could be the result of a shifting population structure as employed young adults move to follow better career opportunities. Once unemployment has risen there is a drop in labor participation rates. We also see a reciprocal relationship between unemployment and housing permit rates. As unemployment increases, the number of housing permits decreases, which in turn is followed by a further increase of unemployment. Additionally, as unemployment increases immigration rate declines within one year.

Figure 11B illustrates that unemployment in CBRM is highly connected to the other variables in the network. It has 11 connections and five of those are immediate feedback loops. Unemployment increases as intraprovincial migration decreases, which in turn is correlated with even higher unemployment. There are also a number of connections with unemployment and the built environment. As unemployment rises, the number of housing permits, starts and completions falls.

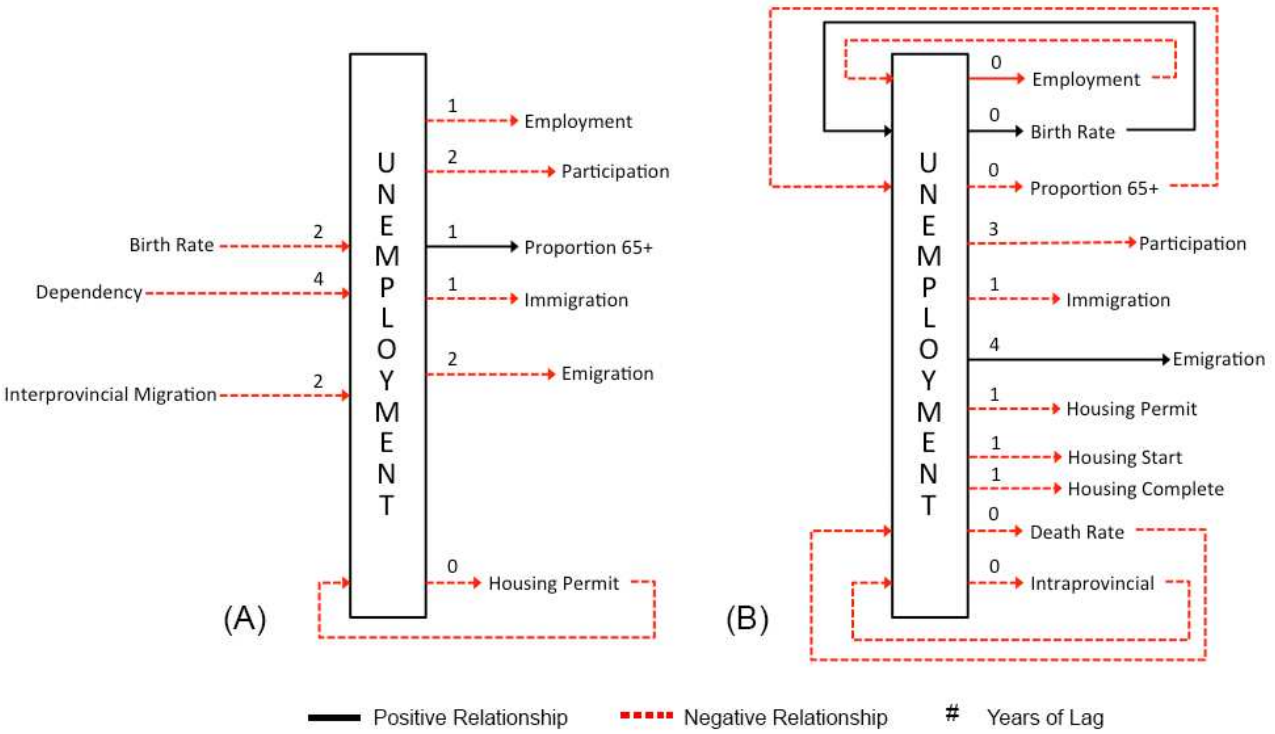

Figure 11: Dynamic variable relationships of key shrinkage factor unemployment in (A) Chatham-Kent and (B) CBRM.

There are significant relationships between unemployment and immigration in both Figure 11A and 11B. Increased unemployment precedes a decline in immigration. In both Chatham-Kent and CBRM there is a one-year time lag between a change in unemployment and the subsequent change in immigration. It can be hypothesized that an increase in unemployment makes for an unattractive locale for new immigrants. Unemployment in both case studies is also firmly related to the built environment. In Chatham-Kent, there is a reciprocal negative relationship between unemployment and housing permits. And in CBRM, there is a negative relationship between unemployment and all three built environment variables (housing permits, starts and completions). As unemployment increases, there is less financial security in the community and consequently, fewer people are in the market to buy homes. Results suggest that a weaker market leads directly to a decrease in housing permits, starts and completions.

Dynamic Trends in Immigration

The relationship between unemployment and immigration is also represented in Figure 12A and 12B. Both figures also show that immigration has a two-way relationship with employment and labor participation. These relationships strengthen the hypothesis of the importance of employment in the immigration process. Conceivably, immigration patterns respond to changes in unemployment, employment and labor participation.

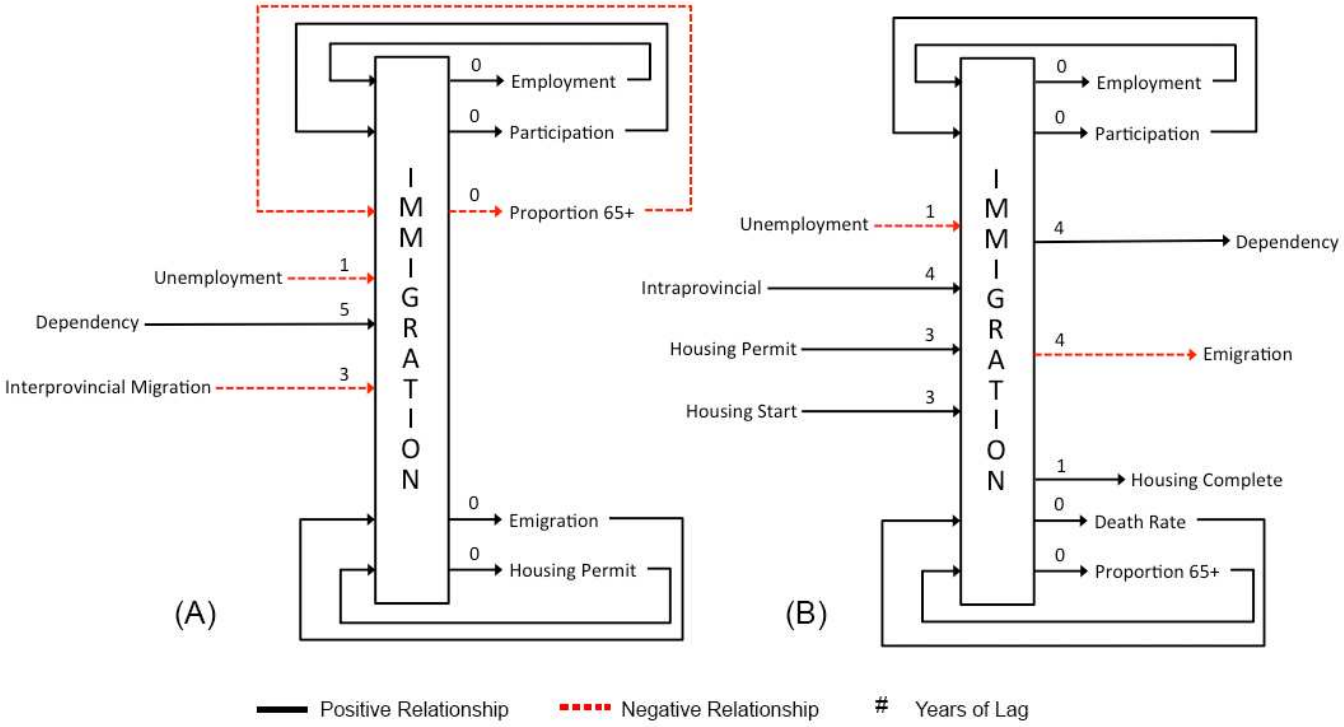

Figure 12: Dynamic variable relationships of key shrinkage factor immigration in (A) Chatham-Kent and (B) CBRM.

In Chatham-Kent (Figure 12A), immigration also has a two-way positive relationship with housing permits. Whereas in CBRM (Figure 12B) changes in both housing permits and starts precede changes in immigration, which are then followed by a change in housing completions. These relationships suggest that the availability of new housing may play a role in immigration settlement patterns. This is especially

true in CBRM as an increase in permits and starts is followed 3 years later by an increase in immigration. And one year after the change in immigration, new housing is completed.

Dynamic Trends in Intraprovincial Migration

A closer inspection of intraprovincial migration (Figure 13A) depicts a number of reciprocal relationships. A decrease in intraprovincial migration is followed by lower birth rates, lower housing start and completion rates, and an increase in non-permanent resident rates. The relationship between intraprovincial migration and housing relationships is logical, as a shrinking population has less of a need for more housing. However, this has further reaching implications, as new housing can be an important factor in attracting young families.

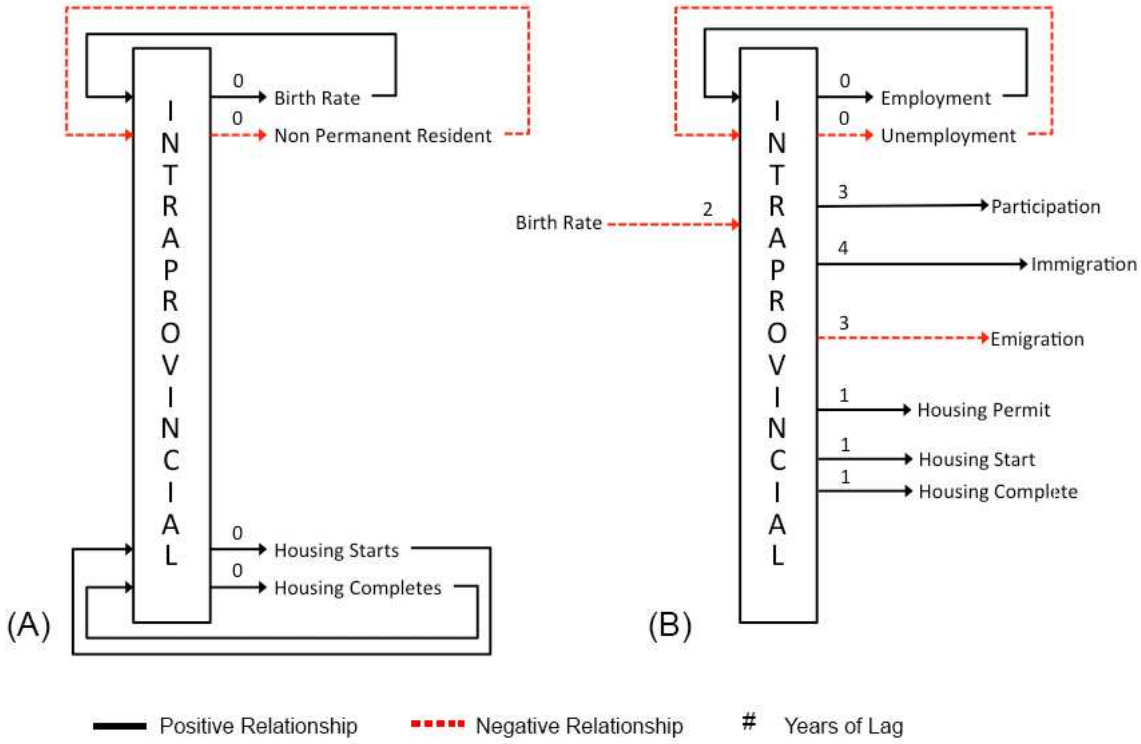

Figure 13: Dynamic variable relationships of key shrinkage factor intraprovincial migration in (A) Chatham-Kent and (B) CBRM.

Intraprovincial migration plays a large role in CBRM's population change. The results in Figure 13B show that a negative change in intraprovincial migration precedes a rise in unemployment, which precedes further decline in intraprovincial migration. As residents leave, labor participation and immigration also fall. Again, there are a number of connections with the built environment. A decline in intraprovincial migration precedes a decline in housing permits, starts and completions.

Dynamic Trends in Interprovincial Migration

Interprovincial migration had fewer relationships than the other migratory variables in both Chatham-Kent and CBRM. However, interprovincial migration rate relationships in Chatham-Kent (Figure 14A) once again show the connection between declining population and rising unemployment. Similar to the trend in immigration, in Chatham-Kent (Figure 14A) there is a relationship between population change and employment. A decrease in interprovincial migration is followed by a decrease in employment and labor participation and an increase in unemployment. Furthermore, a decline in birth rates, potentially reflecting an older population, precedes a decrease in interprovincial migration.

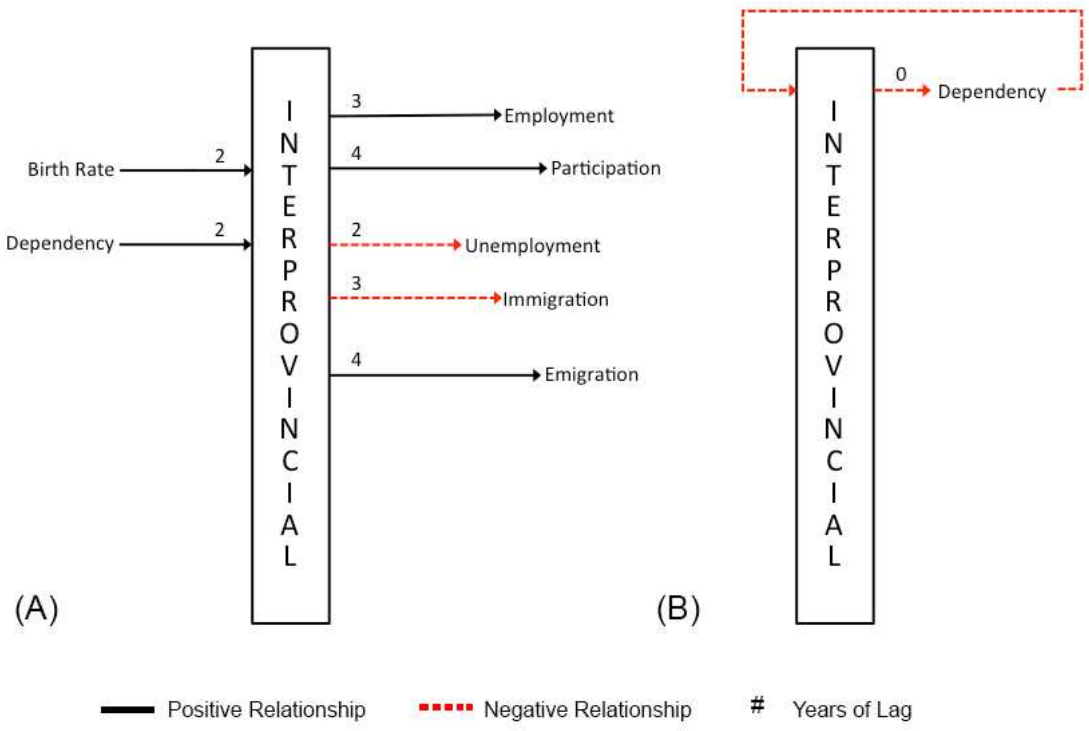

Figure 14: Dynamic variable relationships of key shrinkage factor interprovincial migration in (A) Chatham-Kent and (B) CBRM.

Interprovincial migration (Figure 14B) had only one connection, a direct inverse relationship with dependency ratio. As the number of dependents rises, the number of residents leaving for another province grows.

Discussion

The results of the cross-correlation network analysis in the two case studies demonstrate three outcomes. First, they provide empirical confirmation to Hoekveld's (2012) conclusion that the processes contributing to urban shrinking are extremely complex. The results from both case studies showed extensive connectivity between the variables. Both networks were denser than the theorized conceptual model (Figure 2). Many of the variables were strongly interrelated and the networks displayed numerous feedback loops between all four types of variables. These circular trends potentially indicate self-propagating mechanisms within the urban shrinkage process. Second, the analysis provides empirical

confirmation of the uniqueness of the shrinkage process. Although the two cities are comparable in size and have both experienced symptoms of urban shrinkage, they have considerably different economic and demographic histories. The distinct sets of relationships between variables in each city demonstrates the uniqueness of their shrinking processes.

Third, a number of similarities arose from the analysis of the cross-correlation networks even though the shrinkage process in each case is unique. Unemployment rates were strongly linked to housing permit rates in both cities. Predictably higher unemployment was correlated with fewer housing permits. The built environment provided additional similarities between the cities' trajectories as intraprovincial migration rates were strongly linked to housing starts and completions. A rise in intraprovincial migration led to more housing starts and subsequent completions. This connection was stronger in Chatham-Kent where a two-way relationship was observed. An increase in housing starts and completions led to increased intraprovincial migration. And in both locations, labor variables (unemployment, employment and labor participation rates) were found to be strongly indicative of immigration trends. Specifically, a decrease in employment and labor participation (with a parallel increase in unemployment) led to a decrease in immigration. This suggests that the perception of poor employment prospects acts as a disincentive for immigrants to choose to live in either of these locations. This is especially pertinent in Chatham-Kent, where immigration has been an important source of population growth in the past.

The links between the labor and migratory variables reflect the impact of globalization (see Martinez-Fernandez et al., 2012) in both municipalities and their wider geographic contexts. The economy of Chatham-Kent, and Southwestern Ontario in general, is heavily reliant on mature industries and has declined substantially in recent years. The decision of employers to relocate their manufacturing facilities, such as Navistar's move to Texas and Mexico, is a direct manifestation of economic globalization. Incentivized by lower wages and better government subsidies, multinational companies are more mobile

than in the past. This mobility has shifted the power dynamics in negotiations between private firms and public office. In turn, this has impacted the number and type of jobs available in many shrinking cities such as Chatham-Kent. As reflected in the cross-correlation results, lower levels of employment make it harder to attract and to keep residents.

The negative impact of globalization in CBRM dates much further. The main industrial activities of CBRM have never been locally owned. International investors founded Dominion Coal and Steel in the early 1900s and following Dominion's withdrawal in 1965 the federal government managed the coal and steel industries. Mason (1991) argues that this succession of absentee ownership resulted in a very limited local managerial class. During the 1990s the federal and provincial government began to focus investment in CBRM more on local entrepreneurship. However, the long-time dominance of external owners had resulted in an absence of entrepreneurial culture and the decline continued (Mason, 1991). Over time the employment based has stabilized. However, it is now largely dependent on the retail sector. The connection with globalization can be seen further as, until recently, a significant amount of the CBRM labor force migrated to Alberta. Although the last mine was closed in 2001, the identity of CBRM is still intertwined with the resource extraction industry and the impacts of globalization and absentee ownership continue to play a role in the community.

Conclusion

This paper explored the co-evolution of demographic, migratory, economic and built environment processes in two shrinking municipalities. The goals were to (1) develop a method to analyze and represent numerous complex time series relationships between variables, and (2) to determine the order and influence of the processes contributing to urban shrinkage. In doing so, it advances our understanding of the dynamic processes of urban shrinkage. Furthermore, it responds to the call for research approaches

that "go beyond causality towards more complex and non-linear explanations and interpretations" (Großmann et al., 2013, p. 223). Methodologically the study was inspired by Hoekveld's (2012) use of cross-correlation analysis to explore urban phenomena, Forrester's (1971) system dynamics and Castells' (2004) network society. Although the approach was successful in capturing and representing the strength, time and direction of processes in complex systems, the analysis was limited by the inability to gauge causality. As Hoekveld (2014, p. 58) notes "relations are revealed but not explained." Cross-correlation findings must be augmented with qualitative research regarding the local historic economic, demographic, built environment and migration conditions. By embedding the study's exploratory quantitative findings within the historical context, inferences were made regarding the trajectories of the two municipalities.

The methodological approach to disentangling, analyzing and representing the temporal processes of urban change offers a rich area for additional research. By applying cross-correlation analysis to a large number of shrinking cities, stronger statistical evidence could provide important insight regarding the evolution of urban shrinkage. Further research refining the variables and focusing on the time lags between significant changes in variables, coupled with qualitative research, could help decision-makers to develop more targeted and knowledgeable policy. Considering the explosion in the amount of data readily available to social science researchers and the increased connectivity within and between urban spaces, new methods are needed to analyze and visualize the connections and relationships in complex geographical systems. With a better understanding of the interrelated processes of urban evolution, new policies can be explored to target changes and anticipate prospective trends. And, hopefully, help increase the efficacy of long-term community planning.

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Appendix

Table A.1: Chatham-Kent, ON lag values and correlation coefficients

	Dependency		Proportion 65+		Birth		Death		Immigration		Emigration		Return Emigrants		Temp Emigration		Interprovincial		Intraprovincial		Non Permanent		Unemployment		Employment		Participation		House Permit		House Starts		House Completes	
	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr
Dependency	-	-							5,+	0.63	0,-	-0.69	0,-	-0.82	5,+	0.73	2,+	0.71					4,-	-0.65	5,+	0.70	5,+	0.67						
Proportion 65+			-	-																														
Birth	0,+	0.61			-	-					6,+	0.65	1,-	-0.63	6,+	0.75	2,+	0.87	0,+	0.76	0,-	-0.84	2,-	-0.67	4,+	0.65	5,+	0.63	0,+	0.73				
Death	0,+	0.72					-	-																										
Immigration			0,-	-0.97					-	-																								
Emigration			0,-	-0.81					0,+	0.84	-	-																						
Return Emigrants			5,+	0.68					5,-	-0.80	6,-	-0.84	-	-	4,-	-0.90	2,-	-0.91					4,+	0.82	5,-	-0.87	5,-	-0.85						
Temp Emigration			0,-	-0.79					0,+	0.82	0,+	0.86			-	-																		
Interprovincial									3,-	-0.82	4,+	0.87			2,+	0.90	-	-					2,-	-0.91	3,+	0.93	4,+	0.91						
Intraprovincial																			-	-	0,-	-0.91									0,+	0.78	0,+	0.87
Non Permanent																					-	-							1,-	-0.68	0,-	-0.75	0,-	-0.85
Unemployment			1,+	0.88					1,-	-0.84	2,-	-0.80			0,-	-0.80							-	-	1,-	-0.93	2,-	-0.90	0,-	-0.78				
Employment			0,-	-0.83					0,+	0.86	0,+	0.89			0,+	0.91									-	-	0,+	0.99	0,+	0.66				
Participation			0,-	-0.82					0,+	0.85	0,+	0.93			0,+	0.87											-	-	0,+	0.63				
House Permit			0,-	-0.95					0,+	0.91	0,+	0.67			0,+	0.64													-	-				
House Starts																															-	-	0,+	0.94
House Completes																																	-	-

Table A.2: Cape Breton Regional Municipality, NS lag values and correlation coefficients

	Dependency		Proportion 65+		Birth		Death		Immigration		Emigration		Return Emigrants		Temp Emigration		Interprovincial		Intraprovincial		Non Permanent		Unemployment		Employment		Participation		House Permit		House Starts		House Completes	
	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr	Lag	Corr
Dependency	-	-																											1,-	-0.63				
Proportion 65+			-	-			0,+	0.98	0,+	0.88	2,-	-0.61									0,+	0.71	0,-	-0.76	0,+	0.97	0,+	0.97					0,+	0.82
Birth					-	-					5,+	0.69	1,-	-0.71	6,+	0.75			2,-	-0.77			0,+	0.65					3,-	-0.82	3,-	-0.81		
Death							-	-	0,+	0.80											0,+	0.77	0,-	-0.71	0,+	0.93	0,+	0.93					0,+	0.78
Immigration	4,+	0.62							-	-	3,-	-0.72			3,-	-0.71					2,+	0.74											1,+	0.79
Emigration											-	-	2,+	0.85	0,+	0.95					3,-	-0.64												
Return Emigrants													-	-							6,+	0.71					6,+	0.63	3,+	0.81	2,+	0.83		
Temp Emigration	2,-	-0.65											1,+	0.84	-	-					2,-	-0.74												
Interprovincial	0,-	-0.92															-	-																
Intraprovincial									4,+	0.66	3,-	-0.85	5,-	-0.87	4,-	-0.89			-	-	6,+	0.82	0,-	-0.80	0,+	0.67	3,+	0.64	1,+	0.83	1,+	0.91	1,+	0.89
Non Permanent	1,+	0.64																			-	-					0,+	0.70						
Unemployment	6,-	-0.63							1,-	-0.78	4,+	0.86	6,+	0.71	4,+	0.88					6,-	-0.65	-	-	0,-	-0.88	3,-	-0.74	1,-	-0.68	1,-	-0.70	1,-	-0.83
Employment									0,+	0.91	3,-	0.72			4,-	-0.71									-	-	0,+	0.95					1,+	0.85
Participation									0,+	0.91	1,-	-0.72			1,-	-0.74											-	-						
House Permit									3,+	0.68	3,-	-0.74			3,-	-0.84					5,+	0.84					3,+	0.64	-	-	0,+	0.96	1,+	0.62
House Starts									3,+	0.66	2,-	-0.78			3,-	-0.85					6,+	0.85					3,+	0.62			-	-	1,+	0.70
House Completes											2,-	-0.89	4,-	-0.77	3,-	-0.86					5,+	0.63					0,+	0.86					-	-